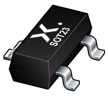


TL431-Q family

Adjustable precision shunt regulators

Rev. 2 — 30 April 2024 — Product data sheet

1. General description

Three-terminal shunt regulator family with an output voltage range between V_{ref} = 2.495 V and 36 V, to be set by two external resistors.

Table 1. Product overview

Reference voltage tolerance (V_{ref})	Temperature range (T_{amb})			Pinning configuration (see Table 5.)
	0 °C to 70 °C	-40 °C to 85 °C	-40 °C to 125 °C	
2.0 %	TL431CDBZR-Q	TL431IDBZR-Q	TL431QDBZR-Q	normal pinning
			TL431FDT-Q	normal pinning
			TL431MFDT-Q	mirrored pinning
1.0 %	TL431ACDBZR-Q	TL431AIDBZR-Q	TL431AQDBZR-Q	normal pinning
			TL431AFDT-Q	normal pinning
			TL431AMFDT-Q	mirrored pinning
0.5 %	TL431BCDBZR-Q	TL431BIDBZR-Q	TL431BQDBZR-Q	normal pinning
			TL431BFDT-Q	normal pinning
			TL431BMFDT-Q	mirrored pinning

2. Features and benefits

- Programmable output voltage up to 36 V
- Three different reference voltage tolerances:
-
    - Standard grade: 2 %
    - A-Grade: 1 %
    - B-Grade: 0.5 %
- Typical temperature drift: 9 mV (in a range of 0 °C up to 70 °C)
- Low output noise
- Typical output impedance: 0.2 Ω
- Sink current capability: 1 mA to 100 mA
- Qualified according to AEC-Q100 (grade 1) and recommended for use in automotive applications

nexperia

3. Applications

- Shunt regulator
- Precision current limiter
- Precision constant current sink
- Isolated feedback loop for Switch Mode Power Supply (SMPS)

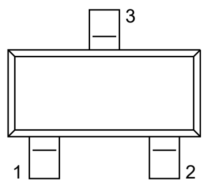
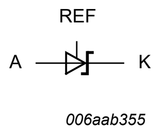
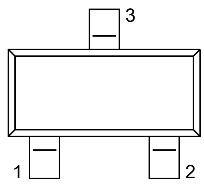
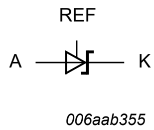
4. Quick reference data

Table 2. Quick reference data

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{KA}	cathode-anode voltage		V_{ref}	-	36	V
I_K	cathode current		1	-	100	mA
V_{ref}	reference voltage	$V_{KA} = V_{ref}$; I_K = 10 mA; T_{amb} = 25 °C				
	• Standard-Grade (2.0 %)		2440	2495	2550	mV
	• A-Grade (1.0 %)		2470	2495	2520	mV
	• B-Grade (0.5 %)		2483	2495	2507	mV

5. Pinning information

Table 3. Pinning

<table>
<tr><th>Pin</th><th>Symbol</th><th>Description</th><th></th><th>Simplified outline</th><th>Graphic symbol</th></tr>
<tr><td colspan="6">SOT23; normal pinning: All types without MFDT ending</td></tr>
<tr><td>1</td><td>K</td><td>cathode</td><td></td><td rowspan="3">
</td><td rowspan="3">
</td></tr>
<tr><td>2</td><td>REF</td><td>reference</td><td></td></tr>
<tr><td>3</td><td>A</td><td>anode</td><td></td></tr>
<tr><td colspan="6">SOT23; mirrored pinning: All types with MFDT ending</td></tr>
<tr><td>1</td><td>REF</td><td>reference</td><td></td><td rowspan="3">
</td><td rowspan="3">
</td></tr>
<tr><td>2</td><td>K</td><td>cathode</td><td></td></tr>
<tr><td>3</td><td>A</td><td>anode</td><td></td></tr>
</table>

6. Ordering information

Table 4. Ordering information

Type number	Package		
	Name	Description	Version
TL431CDBZR-Q	SOT23	plastic surface-mounted package; 3 leads	SOT23
TL431IDBZR-Q			
TL431QDBZR-Q			
TL431FDT-Q			
TL431MFDT-Q			
TL431ACDBZR-Q			
TL431AIDBZR-Q			
TL431AQDBZR-Q			
TL431AFDT-Q			
TL431AMFDT-Q			
TL431BCDBZR-Q			
TL431BIDBZR-Q			
TL431BQDBZR-Q			
TL431BFDT-Q			
TL431BMFDT-Q			

7. Marking

Table 5. Marking codes

Type number	Marking code [1]	Type number	Marking code [1]
TL431CDBZR-Q	CA%	TL431AFDT-Q	AS%
TL431IDBZR-Q	CB%	TL431AMFDT-Q	AV%
TL431QDBZR-Q	CC%	TL431BCDBZR-Q	CG%
TL431FDT-Q	AR%	TL431BIDBZR-Q	CH%
TL431MFDT-Q	AU%	TL431BQDBZR-Q	CJ%
TL431ACDBZR-Q	CD%	TL431BFDT-Q	AT%
TL431AIDBZR-Q	CE%	TL431BMFDT-Q	AW%
TL431AQDBZR-Q	CF%	-	-

[1] % = placeholder for manufacturing site code.

8. Functional diagram

The TL431-Q family comprises a range of 3-terminal adjustable shunt regulators, with specified thermal stability over applicable automotive and commercial temperature ranges. The output voltage can be set to any value between V_{ref} (approximately 2.5 V) and 36 V with two external resistors (see Figure 8). These devices have a typical output impedance of 0.2 Ω. Active output circuitry provides a very sharp turn-on characteristic, making these devices excellent replacements for Zener diodes in many applications like on-board regulation, adjustable power supplies and switching power supplies.

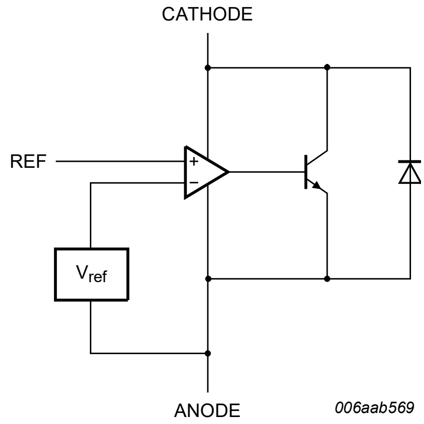


Fig. 1. Functional diagram

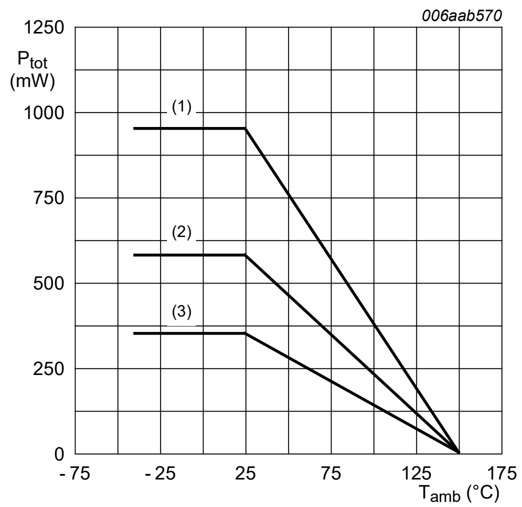
9. Limiting values

Table 6. Limiting values

In accordance with the Absolute Maximum Rating System (IEC 60134).

Symbol	Parameter	Conditions		Min	Max	Unit
V_{KA}	cathode-anode voltage			-	37	V
I_K	cathode current			-100	150	mA
I_{ref}	reference current			-0.05	10	mA
P_{tot}	total power dissipation	$T_{amb} \leq 25$ °C	[1]	-	350	mW
			[2]	-	580	mW
			[3]	-	950	mW
T_j	junction temperature			-	150	°C
T_{amb}	ambient temperature					
	TL431XCDBZR-Q			0	+70	°C
	TL431XIDBZR-Q			-40	+85	°C
	TL431XQDBZR-Q TL431XFDT-Q			-40	+125	°C
T_{stg}	storage temperature			-65	+150	°C

[1] Device mounted on an FR4 Printed-Circuit Board (PCB), single-sided copper, tin-plated and standard footprint.
[2] Device mounted on an FR4 PCB, single-sided copper, tin-plated, mounting pad for anode 1 cm^2.
[3] Device mounted on a ceramic PCB, Al_2O_3, standard footprint.



1. Ceramic PCB, Al_2O_3, standard footprint
2. FR4 PCB, mounting pad for anode 1 cm^2
3. FR4 PCB, standard footprint

Fig. 2. Power derating curves

Table 7. ESD maximum ratings

T_{amb} = 25 °C unless otherwise specified.

Symbol	Parameter	Conditions	Min	Max	Unit
V_{ESD}	electrostatic discharge voltage	MIL-STD-883 (human body model)	-	4	kV

10. Recommended operating conditions

Table 8. Operating conditions

Symbol	Parameter	Conditions		Min	Max	Unit
V_{KA}	cathode-anode voltage			V_{ref}	36	V
I_K	cathode current			1	100	mA

11. Thermal characteristics

Table 9. Thermal characteristics

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
$R_{th(j-a)}$	thermal resistance from junction to ambient	in free air	[1]	-	-	360	K/W
			[2]	-	-	216	K/W
			[3]	-	-	132	K/W
$R_{th(j-sp)}$	thermal resistance from junction to solder point		[4]	-	-	50	K/W

[1] Device mounted on an FR4 PCB, single-sided copper, tin-plated and standard footprint.
[2] Device mounted on an FR4 PCB, single-sided copper, tin-plated, mounting pad for anode 1 cm^2.
[3] Device mounted on a ceramic PCB, Al_2O_3, standard footprint.
[4] Soldering point of anode.

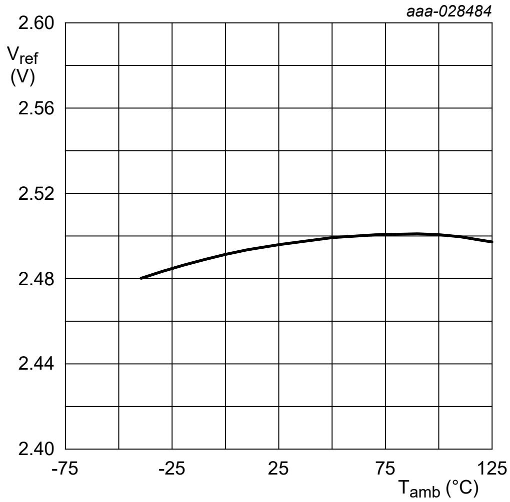
12. Characteristics

Table 10. Characteristics

T_{amb} = 25 °C unless otherwise specified.

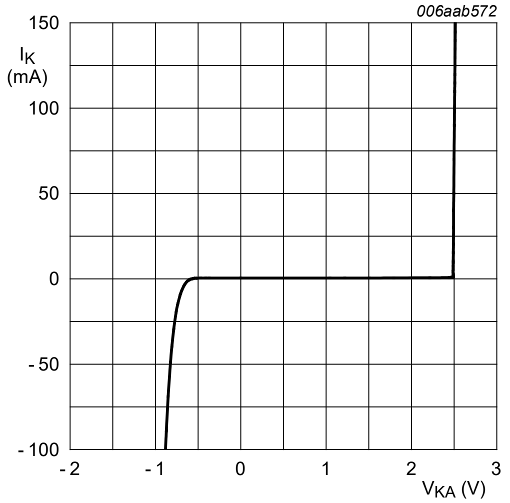
Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Standard-Grade (2.0 %): TL431CDBZR-Q; TL431IDBZR-Q; TL431QDBZR-Q; TL431FDT-Q; TL431MFDT-Q						
V_{ref}	reference voltage	V_{KA} = V_{ref}; I_K = 10 mA	2440	2495	2550	mV
ΔV_{ref}	reference voltage variation	V_{KA} = V_{ref}; I_K = 10 mA				
	TL431CDBZR-Q	T_{amb} = 0 °C to 70 °C	-	9	16	mV
	TL431IDBZR-Q	T_{amb} = -40 °C to 85 °C	-	17	34	mV
	TL431QDBZR-Q	T_{amb} = -40 °C to 125 °C				
	TL431FDT-Q					
	TL431MFDT-Q					
$\Delta V_{ref}/\Delta V_{KA}$	reference voltage variation to cathode -anode voltage variation ratio	I_K = 10 mA				
		ΔV_{KA} = 10 V to V_{ref}	-	-1.4	-2.7	mV/V
		ΔV_{KA} = 36 V to 10 V	-	-1	-2	mV/V
I_{ref}	reference current	I_K = 10 mA; R1 = 10 kΩ; R2 = open	-	2	4	μA
ΔI_{ref}	reference current variation	I_K = 10 mA; R1 = 10 kΩ; R2 = open				
	TL431CDBZR-Q	T_{amb} = 0 °C to 70 °C	-	0.4	1.2	μA
	TL431IDBZR-Q	T_{amb} = -40 °C to 85 °C	-	0.8	2.5	μA
	TL431QDBZR-Q	T_{amb} = -40 °C to 125 °C				
	TL431FDT-Q					
	TL431MFDT-Q					
$I_{K(min)}$	minimum cathode current	V_{KA} = V_{ref}	-	0.4	1	mA
I_{off}	off-state current	V_{KA} = 36 V; V_{ref} = 0	-	0.1	1	μA
Z_{KA}	dynamic cathode-anode impedance	I_K = 0.1 mA to 100 mA; V_{KA} = V_{ref}; f < 1 kHz	-	0.20	0.5	Ω
A-Grade (1 %): TL431ACDBZR-Q; TL431AIDBZR-Q; TL431AQDBZR-Q; TL431AFDT-Q; TL431AMFDT-Q						
V_{ref}	reference voltage	V_{KA} = V_{ref}; I_K = 10 mA	2470	2495	2520	mV
ΔV_{ref}	reference voltage variation	V_{KA} = V_{ref}; I_K = 10 mA				
	TL431ACDBZR-Q	T_{amb} = 0 °C to 70 °C	-	9	16	mV
	TL431AIDBZR-Q	T_{amb} = -40 °C to 85 °C	-	17	34	mV
	TL431AQDBZR-Q	T_{amb} = -40 °C to 125 °C				
	TL431AFDT-Q					
	TL431AMFDT-Q					
$\Delta V_{ref}/\Delta V_{KA}$	reference voltage variation to cathode-anode voltage variation ratio	I_K = 10 mA				
		ΔV_{KA} = 10 V to V_{ref}	-	-1.4	-2.7	mV/V
		ΔV_{KA} = 36 V to 10 V	-	-1.0	-2.0	mV
I_{ref}	reference current	I_K = 10 mA; R1 = 10 kΩ; R2 = open	-	2.0	4.0	μA

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
ΔI_{ref}	reference current variation	I_K = 10 mA; R1 = 10 kΩ; R2 = open				
	TL431ACDBZR-Q	T_{amb} = 0 °C to 70 °C	-	0.4	1.2	μA
	TL431AIDBZR-Q	T_{amb} = -40 °C to 85 °C	-	0.8	2.5	μA
	TL431AQDBZR-Q	T_{amb} = -40 °C to 125 °C				
	TL431AFDT-Q					
	TL431AMFDT-Q					
$I_{K(min)}$	minimum cathode current	V_{KA} = V_{ref}				
	TL431ACDBZR-Q	T_{amb} = 0 °C to 70 °C	-	0.4	0.6	mA
	TL431AIDBZR-Q	T_{amb} = -40 °C to 85 °C				
	TL431AQDBZR-Q	T_{amb} = -40 °C to 125 °C				
	TL431AFDT-Q					
	TL431AMFDT-Q					
I_{off}	off-state current	V_{KA} = 36 V; V_{ref} = 0	-	0.1	0.5	μA
Z_{KA}	dynamic cathode-anode impedance	I_K = 0.1 mA to 100 mA; V_{KA} = V_{ref}; f < 1 kHz	-	0.2	0.5	Ω
B-Grade (0.5 %): TL431BCDBZR-Q; TL431BIDBZR-Q; TL431BFDT-Q; TL431BMFDT-Q						
V_{ref}	reference voltage	V_{KA} = V_{ref}; I_K = 10 mA	2483	2495	2507	mV
ΔV_{ref}	reference voltage variation	V_{KA} = V_{ref}; I_K = 10 mA				
	TL431BCDBZR-Q	T_{amb} = 0 °C to 70 °C	-	9	16	mV
	TL431BIDBZR-Q	T_{amb} = -40 °C to 85 °C	-	17	34	mV
	TL431BQDBZR-Q	T_{amb} = -40 °C to 125 °C				
	TL431BFDT-Q					
	TL431BMFDT-Q					
$\Delta V_{ref}/\Delta V_{KA}$	reference voltage variation to cathode-anode voltage variation ratio	I_K = 10 mA				
		ΔV_{KA} = 10 V to V_{ref}	-	-1.4	-2.7	mV/V
		ΔV_{KA} = 36 V to 10 V	-	-1.0	-2.0	mV/V
I_{ref}	reference current	I_K = 10 mA; R1 = 10 kΩ; R2 = open	-	2.0	4.0	μA
ΔI_{ref}	reference current variation	I_K = 10 mA; R1 = 10 kΩ; R2 = open				
	TL431BCDBZR-Q	T_{amb} = 0 °C to 70 °C	-	0.4	1.2	μA
	TL431BIDBZR-Q	T_{amb} = -40 °C to 85 °C	-	0.8	2.5	μA
	TL431BQDBZR-Q	T_{amb} = -40 °C to 125 °C				
	TL431BFDT-Q					
	TL431BMFDT-Q					
$I_{K(min)}$	minimum cathode current	V_{KA} = V_{ref}				
	TL431BCDBZR-Q	T_{amb} = 0 °C to 70 °C	-	0.4	0.6	mA
	TL431BIDBZR-Q	T_{amb} = -40 °C to 85 °C				
	TL431BQDBZR-Q	T_{amb} = -40 °C to 125 °C				
	TL431BFDT-Q					
	TL431BMFDT-Q					
I_{off}	off-state current	V_{KA} = 36 V; V_{ref} = 0	-	0.1	0.5	μA
Z_{KA}	dynamic cathode-anode impedance	I_K = 0.1 mA to 100 mA; V_{KA} = V_{ref}; f < 1 kHz	-	0.2	0.5	Ω



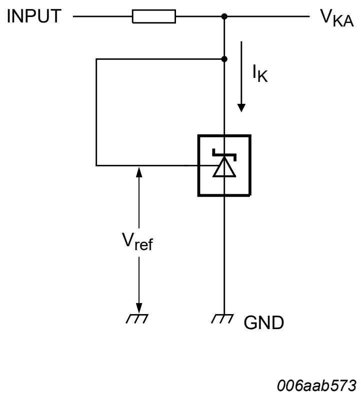
I_K = 10 mA; V_{KA} = V_{ref}

Fig. 3. Reference voltage as a function of ambient temperature; typical values



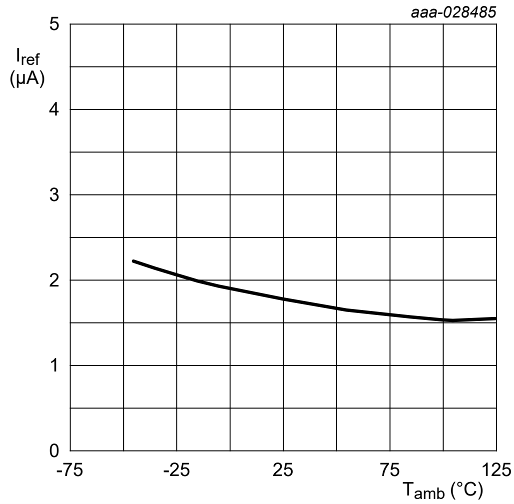
V_{KA} = V_{ref}; T_{amb} = 25 °C

Fig. 4. Cathode current as a function of cathode-anode voltage; typical values



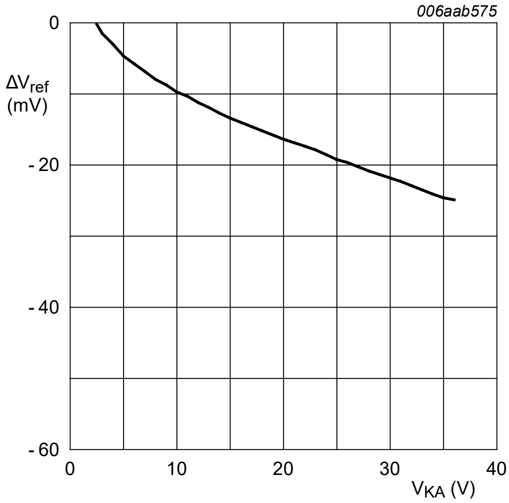
I_K = 10 mA; V_{KA} = V_{ref}

Fig. 5. Test circuit to Figures 3 and 4



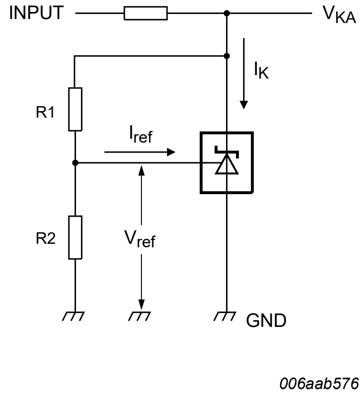
I_K = 10 mA; R1 = 10 kΩ; R2 = open

Fig. 6. Reference current as a function of ambient temperature; typical values



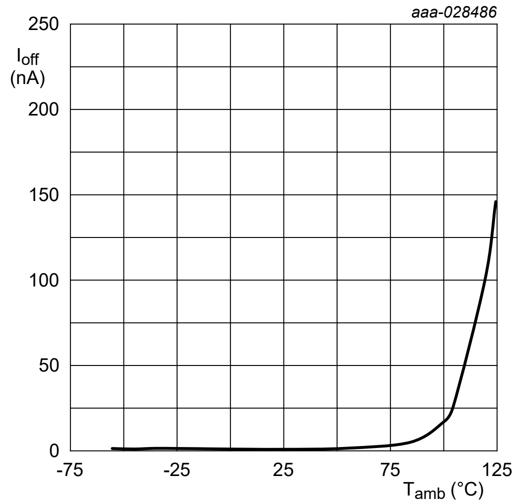
I_K = 10 mA; T_{amb} = 25 °C

Fig. 7. Reference voltage variation as a function of cathode-anode voltage; typical values



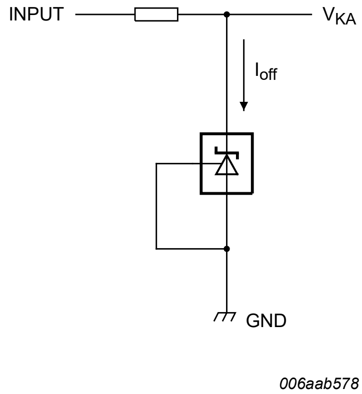
$$V_{KA} = V_{ref} \times \left(1 + \frac{R1}{R2}\right) + I_{ref} \times R1$$

Fig. 8. Test circuit to Figures 6 and 7



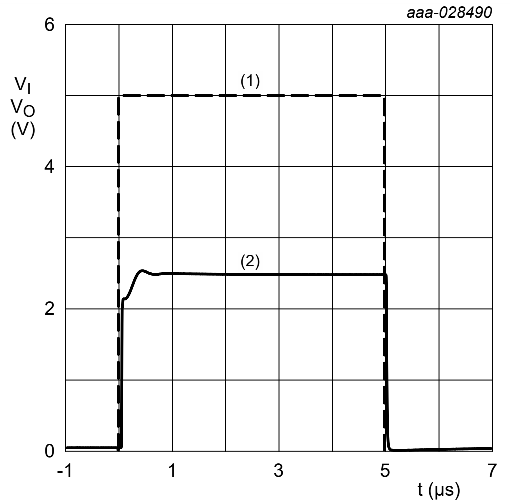
V_{KA} = 36 V; V_{ref} = 0 V

Fig. 9. Off-state current as a function of ambient temperature; typical values



V_{KA} = 36 V; V_{ref} = 0 V

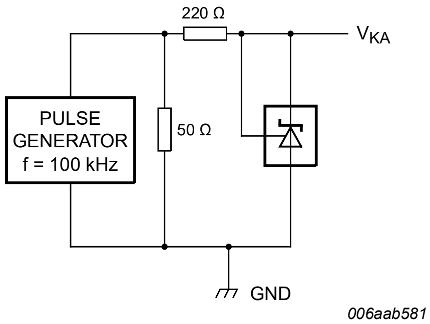
Fig. 10. Test circuit to Figure 9



1. input
2. output

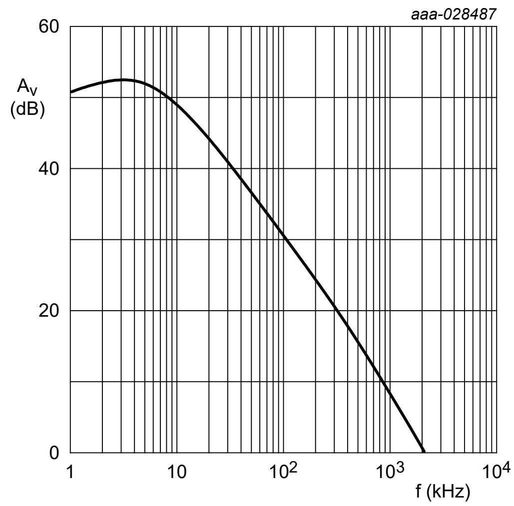
T_{amb} = 25 °C

Fig. 11. Input voltage and output voltage as a function of time; typical values



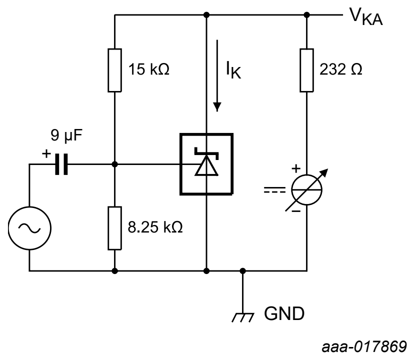
T_{amb} = 25 °C

Fig. 12. Test circuit to Figure 11



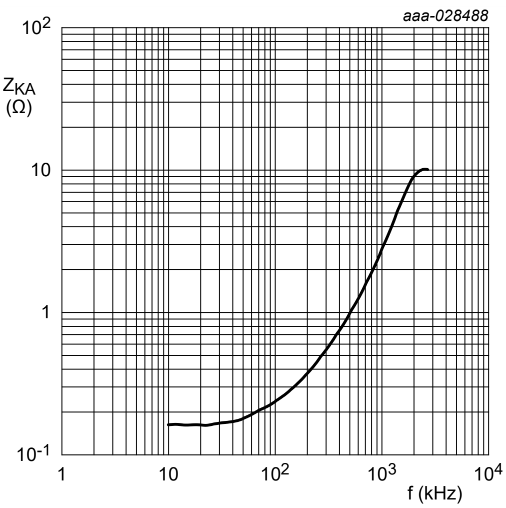
I_K = 10 mA; T_{amb} = 25 °C

Fig. 13. Voltage amplification as a function of frequency; typical values



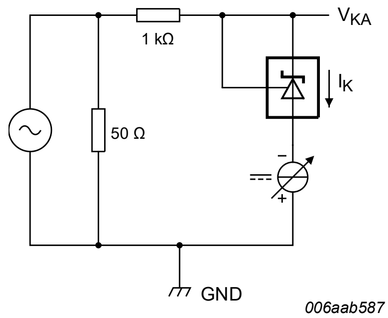
I_K = 10 mA; T_{amb} = 25 °C

Fig. 14. Test circuit to Figure 13



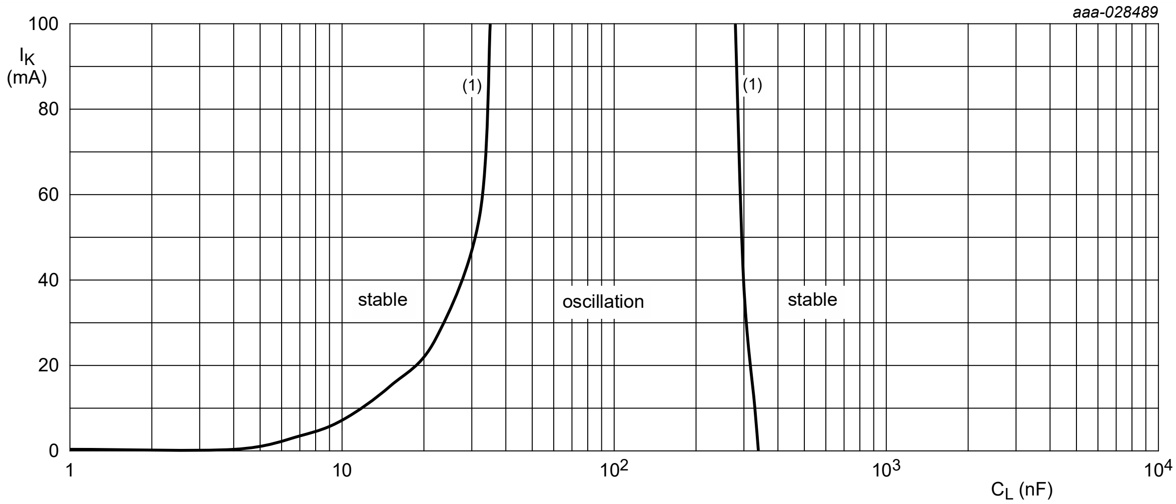
I_K = 10 mA; T_{amb} = 25 °C

Fig. 15. Dynamic cathode-anode impedance as a function of frequency; typical values



I_K = 10 mA; T_{amb} = 25 °C

Fig. 16. Test circuit to Figure 15



T_{amb} = 25 °C

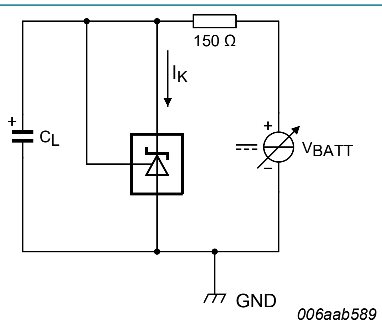
(1) V_{KA} = V_{ref}

V_{KA} = 5 V; no oscillation

V_{KA} = 10 V; no oscillation

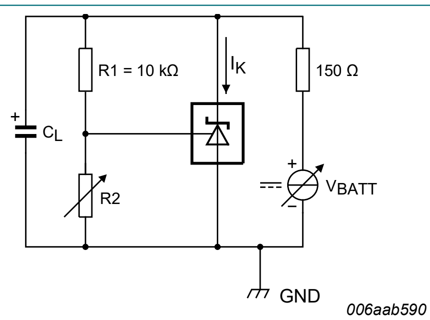
V_{KA} = 15 V; no oscillation

Fig. 17. Cathode current as a function of load capacitance, typical values



V_{KA} = V_{ref}; T_{amb} = 25 °C

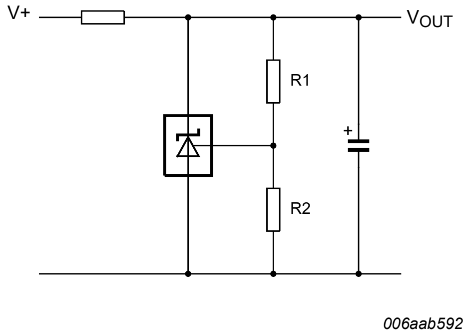
Fig. 18. Test circuit to Figure 17



V_{KA} > 5 V; stable operation; T_{amb} = 25 °C

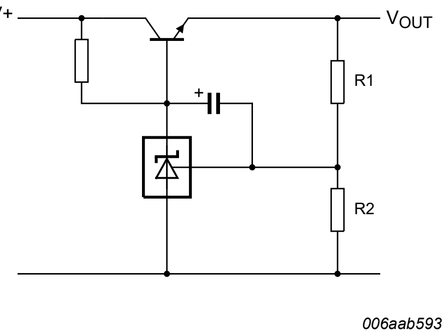
Fig. 19. Test circuit to Figure 17

13. Application information



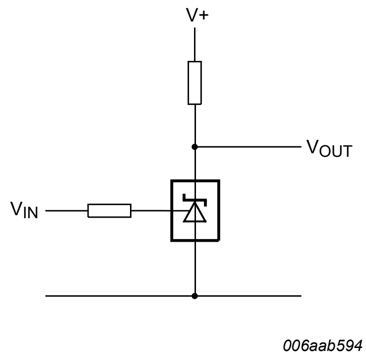
$$V_{OUT} = \left(1 + \frac{R1}{R2}\right) \times V_{ref}$$

Fig. 20. Shunt regulator



$$V_{OUT} = \left(1 + \frac{R1}{R2}\right) \times V_{ref} \quad V_{OUT(min)} = V_{ref} + V_{be}$$

Fig. 21. Series pass regulator

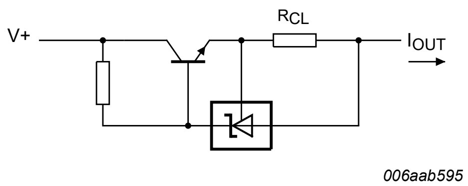


$V_{th} = V_{ref}$

$V_{IN} < V_{ref} \Rightarrow V_{OUT} > 0$

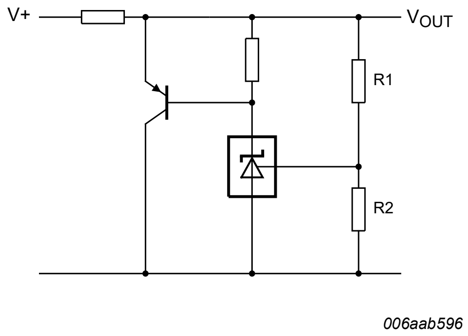
$V_{IN} > V_{ref} \Rightarrow V_{OUT} \cong 2$

Fig. 22. Single-supply comparator with temperature-compensated threshold



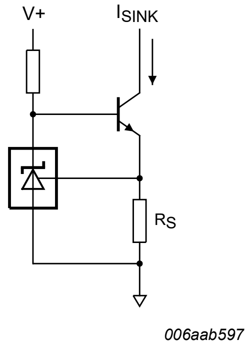
$$I_{OUT} = \frac{V_{ref}}{R_{CL}} + I_{KA}$$

Fig. 23. Constant current souce



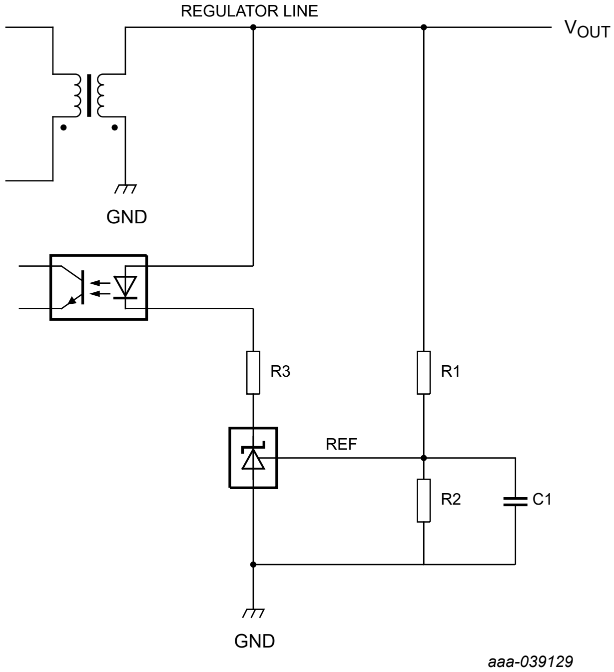
$$V_{OUT} = \left(1 + \frac{R1}{R2}\right) \times V_{ref}$$

Fig. 24. High-current shunt regulator



$$I_{SINK} = \frac{V_{ref}}{R_S}$$

Fig. 25. Constant current sink



A small capacitor C1 (about 100 pF) is recommended at the V_{ref} input to damp switching pulses that can get injected into the V_{ref} signal from the primary side.

Fig. 26. TL431 in control loop of SMPS

14. Test information

Quality information

This product has been qualified in accordance with the Automotive Electronics Council (AEC) standard Q100 - Failure mechanism based stress test qualification for integrated circuits, and is suitable for use in automotive applications.

15. Package outline

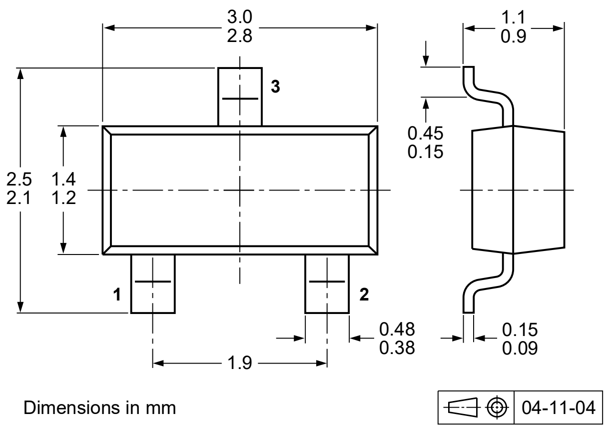


Fig. 27. Package outline SOT23

16. Soldering

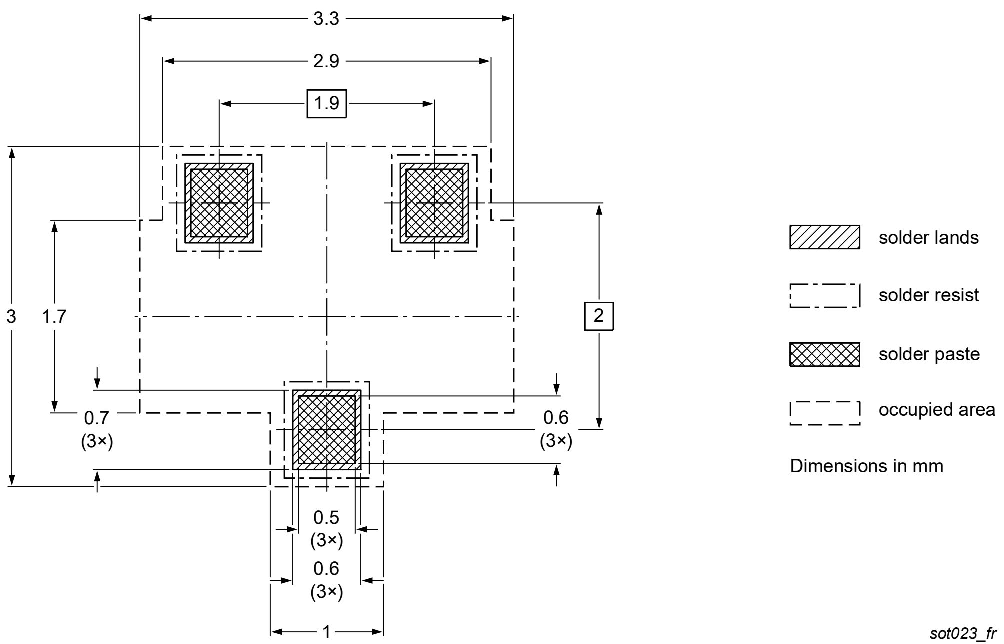


Fig. 28. Reflow soldering footprint SOT23

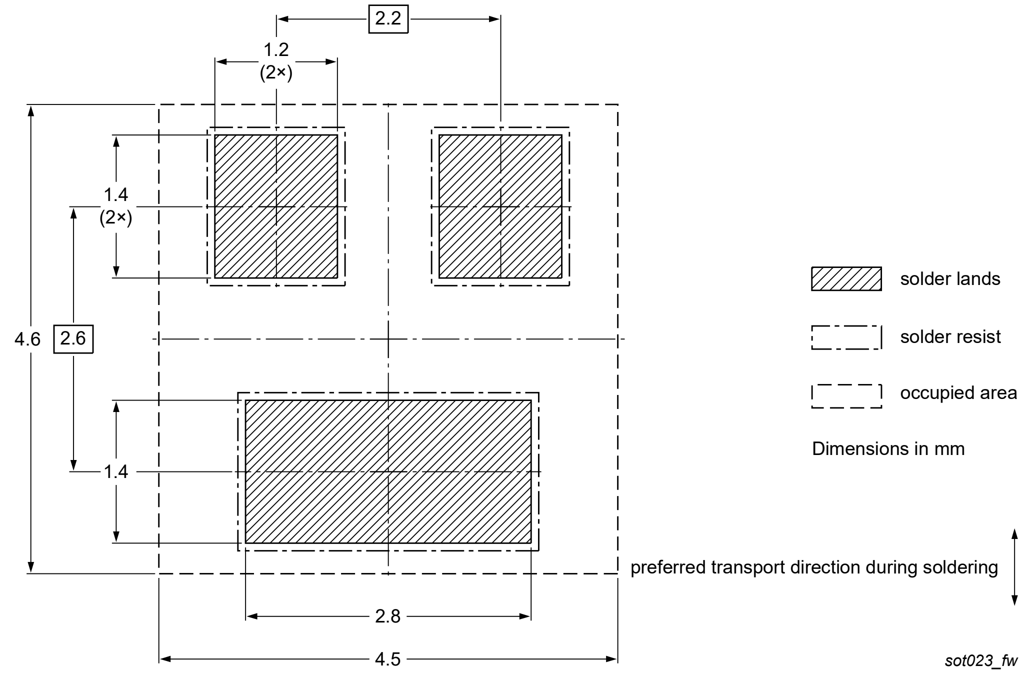


Fig. 29. Wave soldering footprint SOT23

17. Revision history

Table 11. Revision history

Document ID	Release date	Data sheet status	Change notice	Supersedes
TL431-Q_FAM v.2	20240430	Product data sheet	-	TL431-Q_FAM v.1
Modification	• Application information: Legend of Fig. 22 and graph of Fig. 26 adapted			
TL431-Q_FAM v.1	20230512	Product data sheet	-	-

18. Legal information

Data sheet status

Document status [1][2]	Product status [3]	Definition
Objective [short] data sheet	Development	This document contains data from the objective specification for product development.
Preliminary [short] data sheet	Qualification	This document contains data from the preliminary specification.
Product [short] data sheet	Production	This document contains the product specification.

[1] Please consult the most recently issued document before initiating or completing a design.
[2] The term 'short data sheet' is explained in section "Definitions".
[3] The product status of device(s) described in this document may have changed since this document was published and may differ in case of multiple devices. The latest product status information is available on the internet at https://www.nexperia.com.

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